AN ECOLOGICAL SURVEY OF FLAT ROCK MOUNTAIN

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Master of Arts

by

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A special note of thanks is given to the National Park Service who generously consented for this study to be made at Flat Rock along the Blue Ridge Parkway.

For his collaboration on the many problems, this thesis is dedicated to

MY HUSBAND

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CHAPTER I

INTRODUCTION

Many environmental factors are exerting their influence upon every form of life. The study of this relationship between organisms and their environment in the Flat Rock area is the theme for this thesis. Since ecology includes everything that may affect an organism in any way, it is a complex of factors that must always be considered in terms of their interacting effects upon organisms and each other (30). The name ecology first appeared as "oecology" (30) in 1869. Modern ecology has developed mainly since 1900, but its origin goes as far back as the Greeks (42).

It must be emphasized that neither plant ecology nor animal ecology is completely independent of the other. They are not isolated groups, but are part of a complex whole, and their relationship to each other cannot be excluded.

Plant ecology is divided into autecology, which is the study of the interrelationships between the individual and its environment, and synecology, which is the study of the structure and development of the community. For example, if a study is made of the relation of a Rhododendron, or a group of Rhododendrons, to the environment, the approach would be autecology. If the study concerned the forest in which the Rhododendron lives, the approach would be synecology.

Purpose of the Study

The purpose of this thesis is to make an ecological survey of plant life on Flat Rock Mountain, located in Avery County, North Carolina. This involves studying and identifying the plant communities of that area, their structure, development, and causes of distribution.

A secondary purpose is to collect and identify two specimens of as many species as possible of the plants found in the area, one for the herbarium of Appalachian State Teachers College and the other for the National Park Service. Permission was granted by the acting superintendent of the Blue Ridge Parkway to make these collections.

Need for the Study

". . . what science calls for today are life histories, and ecological studies — the precise measurement of the environmental factors and the inter-relations of organisms." (31, p. 345)

As far as can be determined no ecological investigations of this specific area have been recorded. Reed, in 1905, studied the vegetation of 16,000 acres in the Grandfather Mountain area, but did not make a specific study of the Flat Rock area (57). This study will provide much needed information concerning the floristics of western North Carolina.

It is necessary for mankind as a whole to have an intelligent knowledge of the environment if our complex civilization is to survive, since the basic laws of nature have not been repealed; only their complexion and quantitative relations have changed, as the world's human population has increased (29).

Preview of Organization of the Thesis

Chapter II deals with the methods of procedure in making this study. The description of the area, which includes a map, is followed by a description of the quadrats and fifth-acre plots.

Chapter III is concerned with site factors which involve two types of environment, the physical and the biotic. Physical environment includes the geologic, physiographic, climatic, and edaphic factors, while biotic environment includes the relationship with other organisms, both plant and animal.

Chapter IV is a study of the successions on other bare rock areas as compared with Flat Rock. It includes the stages of succession and the species important in each. The ecologist is not only concerned with the life of the area in the past, but also with what the natural future may be. These thoughts provided the basis for this chapter.

Chapter V discusses the plant groupings or communities. The important aspect here was the determination of the ecological structure and the floristics of the area with charts to illustrate the dominant and secondary species.

Chapter VI, the last chapter, summarizes and evaluates the data gathered with emphasis on the conclusions reached. This followed by an animal list, an annotated species list, and a list of specimens placed in the college herbarium.

Review of the Literature

Much has been written in regard to the many problems in the field of plant ecology. These problems frequently overlap those of other applied fields, such as conservation, forestry, and agriculture. There is much diversity of subject matter included in ecology which results in many fields of specialization.

While many articles and books have been written on the subject of plant ecology there is a limited amount written on that of the Grandfather Mountain or Linville area. Michaux in 1796 studied and identified some of the flora of western North Carolina but did not concern himself with the ecological structure (60). Braun (1940) compared Reed's study (1905) of the original forest types of that area with the types or slopes in existence today (4). Much of this original forest has been destroyed, either by fire, cutting, or chestnut blight, yet some of the types characterized by Reed may still be distinguished. This thesis offers an opportunity for comparison of the original Grandfather Mountain region with the specific forest area of the present Flat Rock area.

The sequence of plant succession of exposed rocks has been determined with reasonable accuracy. Some studies have been done on the succession of plants on bare rock surfaces in sections of North Carolina other than the Flat Rock area.

Cooper (1913) studied the vegetation of Isle Royale, Lake Superior, which is a situation comparable to that of the Flat Rock area. He concluded that crustose and foliose lichens preceded and prepared the way for the mosses which followed (53). In addition, Cooper compared the conifer forest of the southern Appalachian summits with the Isle Royale forest. These are isolated areas which seem like detached portions of the great northeastern forest. Many of the genera are the same but the species are different. In general aspect the forest is remarkably similar to that of Isle Royale. The localities of these studies were Richland Balsam, Plott Balsam, and Mt. Mitchell (49).

Cooper (1912) made a study of the ecological succession of mosses on Isle Royale. He found that mosses play a very important role in the successional development of the climax forest. Their principal function is the accumulation of humus and the conservation of soil moisture. The most widely distributed species and the one contributing most to the establishment of the climax forest is <u>Calliergon</u> <u>Schreberi</u> (50).

Taylor (1920) investigated the ecology of Carrol Creek

Canyon, which is about 125 miles west of Chicago. Liverworts and crustose lichens were found to be the pioneers of this region (58).

Oosting and Anderson (1937) made a study of a barren outcrop of rock in Jackson County, North Carolina. Their examinations showed that the early moss pioneers occupied the rock regardless of whether crustose lichens were present or absent. Those which started on a patch of crustose lichen seemed to have no advantage over those starting on bare rock (56). Frye (1927) showed that crustose lichens collect small amounts of soil and aid in actual disintegration of rock itself, but are of little importance in aiding later pioneers (56).

> A few studies of the development of vegetation upon bare rock have been made in widely separated sections of the country. These show that the progression of growth forms and even of certain genera is remarkably similar everywhere. (55, p. 750)

Oosting and Anderson (1939) studied the succession on granite rock in eastern North Carolina and compared it with their previous study made in Jackson County. They found the crustose lichens to be pioneers in both habitats, but the lichens did not play an important role in the development of later stages of vegetation. They neither hindered nor contributed to the normal line of development (55).

Keever and others (1951) studied the vegetation on exposed granite on Rocky Face Mountain, Alexander County, North Carolina, but found that the crustose and foliose lichens do not necessarily precede the first mosses. _Grimmia laevigata_ (Brid.) Brid., _Rhacomitrium heterostichum_ (Hedw.) Brid. var. _ramulosum_ (Lindb.) Jones, and _Andreaea rothii_ Web. and Mohr. were observed and photographed growing directly on granite without being preceded by lichens. In these studies it was shown that plant succession on rock never proceeds without the presence of a moss, therefore, mosses should be considered the true pioneers in this succession (53).

Keever (1957) studied the reproduction of _Grimmia laevigata_ to determine the plant succession on granite. She concluded that some vegetative means of reproduction is largely responsible for the propogation of _Grimmia_, which seems rarely to produce sporophytes. The protonema is very drought resistant, thus increasing its adhesive power to rock in proportion to the length of the period without water (53).

Link (1795) stated that _Lichen candelarius_ was the first lichen to appear on the rocks he observed, with _Lichen parietinus_ and _Lichen tenellus_ following soon after (38). Bachmann (1914) made a study of the lichens of acid and basic rocks. He concluded that in his case it was the physical rather than the chemical which effected the lichen flora (38).

CHAPTER II

METHODS OF PROCEDURE

Description of the Area

Flat Rock is located south of Linville in Avery County, North Carolina. It is four miles southwest of Grandfather Mountain and along the Blue Ridge Parkway at milepost 308.3. The area mapped and studied comprises about thirty-four acres, part of this being forest and part a large outcrop of rock. The bare rock extends approximately eight hundred feet in a north-south direction. The vegetated portion of the rock extends some two hundred feet beyond the bare area on the north slope. The rock extends some three hundred fifty feet at its widest point in an east-west direction. See Figure 1, page 9.

Description of Quadrats and Fifth-Acre Plots

The quadrat method is a basic method for many types of ecological investigations. It is also known as the sample-plot method, a term commonly used by many ecologists. Cain (1943) described two principal types of sample-plot method (48). First, the single plot method employs only one sample area to a stand. Second, the multiple plot method employs several small areas examined in a stand. The single plot method has a distinct disadvantage because the location is partially subjective and no single plot is likely to be strictly average.

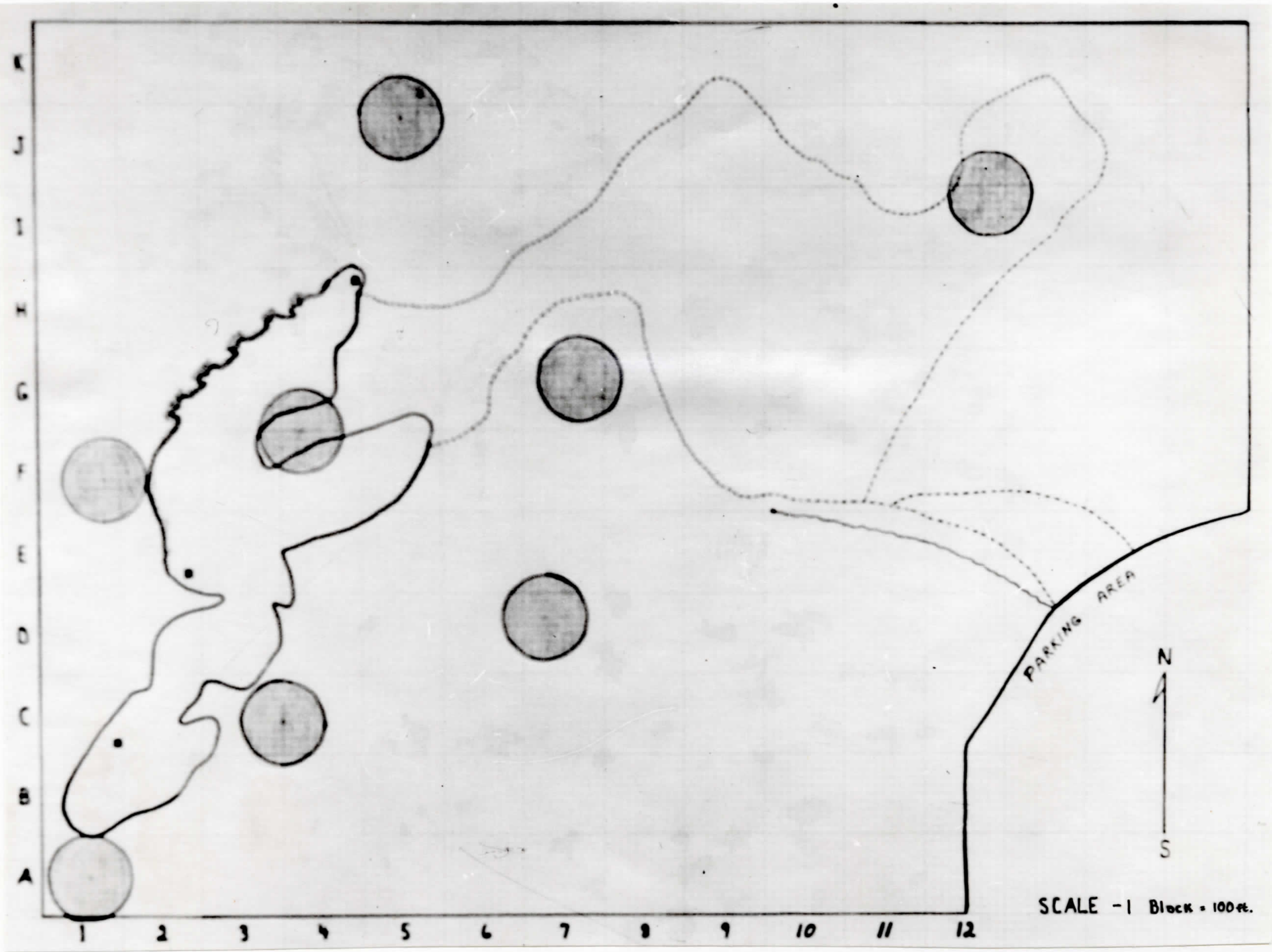

FIGURE 1

MAP OF FLAT ROCK AREA SHOWING LOCATION OF QUADRATS (●) AND FIFTH-ACRE PLOTS (circles)

It cannot completely represent a community.

The basic principle underlying the quadrat method is the selection of sample plots to give data which will yield an accurate representation of the whole area. Small quadrats are scattered through the community, the number depending upon the size of the community and the character of the vegetation. Figure 1 shows the location of the quadrats in the Flat Rock area. The locations of these quadrats were selected with care to give as accurate a picture as possible and to reveal the entire range of vegetative structure. "The quadrat, like any other method, must be used with discrimination and it should be rarely located at random." (41, p. 11) Systematic sampling is better than random sampling for ecological purposes.

The size of the quadrats used in this study were a mill acre (6.6' x 6.6') and of the list quadrat type to determine the kinds and abundance of plants. The listing of the species in various parts of the area gave definite information as to the composition of the vegetation. It not only revealed the species of plants that occurred in a particular habitat, but also the species which the habitat did not support.

Eight fifth-acre plots were used to determine the woody plants within and along the edge of the forest. These plots were chosen with discrimination in various areas to reveal different vegetative structures as influenced by the rock.

The boundary for each fifth-acre plot was then determined by laying out a circular area with a radius of fifty-five feet and marking a tree for its center. The primary purposes of the tree count were to determine the species represented in each plot and their numbers and sizes. The sizes of the trees included the approximate height and the diameter breast high, measured by a tape graduated to read diameter. The actual counting of trees was done by stretching a fifty-five foot rope from the center tree so that the circular area was broken up into sectors. Starting with the center tree and moving out to the end of the rope, the trees in each sector were then counted. A team of two persons was used in making this count.

To facilitate location and identification of plots, the Flat Rock area was divided into squares of one hundred feet. Each square was numbered according to its position in relation to the southwest corner of the map. From west to east the squares were numbered 1 to 15. From south to north the squares were arranged alphebetically A to K. The location of these plots is shown in Figure 1, page 9.

The central point of Plot # A-1 is located about fifty-five feet south of the southern tip of the rock. The edge of the plot meets the edge of the rock and was chosen to reveal the type of vegetation gaining a foothold on the rock. The soil is very thin here.

The central point of Plot # C-3 is located approximately eighty feet east of the rock in the southeastern portion of the area. This area was chosen to determine the structure of the vegetation as influenced by the closeness of the rock. It is sheltered from the wind by both the rock and a dense area of hemlocks which border this portion of the western boundary of the rock.

The central point of Plot # D-7 is located approximately 325 feet from the eastern edge of the rock. At this point the plot is almost half the distance between the rock and the eastern boundary. The plot lies in a hollow and was chosen to show the influence of a sheltered vegetation in a deeper soil than in any of the other plots.

The central point of Plot # F-1 is located approximately fifty feet west of the western boundary of the rock. The site was chosen to determine those plants which are moving up on the rock. The slope is steep and the soil is very thin in this area.

The central point of Plot # F-4 is located on top of the rock in a vegetated area protruding out on the rock. This area is under the influence of a continuous wind and a shallow soil. It was chosen to reveal those plants adapted to withstand these two extremes in environment.

The central point of Plot # G-7 is located approximately one hundred feet from the trail and on a rocky ridge. It was chosen to compare its vegetation with that of D-7, which is in the hollow below it at a distance of nearly three hundred feet.

The central point of Plot # I-12 is located in the northwest portion of the area at a point between the curving of the trail. This is on a ridge in an area where there are several large outcrops of rocks. Being seven to eight hundred feet from the main rock, this plot was chosen for study to determine any difference in vegetation that might have been caused by its distance from the rock.

The central point of Plot # J-5 is located approximately two hundred feet north of the northern boundary of the rock. There is practically no soil except in the crevices of the rock. The point of location is on the rock itself. It was chosen to show those species of plants which had moved in on this xerophytic location. Vegetation in this location is under the influence of constant winds.

CHAPTER III

SITE FACTORS

I. GEOLOGICAL

By early Cenozoic time nearly all of the Appalachian region was peneplaned, except a chain of monadnocks 2,000 to 3,000 feet in height along the border of eastern Tennessee and western North Carolina. These areas form the crest of the present Great Smoky Mountains, which show no evidence of having ever been reduced to a level summit. In the Appalachian region there are widespread remains of a flat erosion surface preserved in the even crests of the highest ridges of the folded belt. This surface is known as the Schooley peneplain (37).

The existing relief in the Appalachian Mountains is due almost entirely to Cenozoic changes. It is the result of a series of broad regional upwarps, which resulted in the present elevation, and erosion, which etched out the weaker rocks and produced the local relief. The mountain structures were present at this time, being inherited from the Appalachian revolution. Local Triassic faulting has produced the only changes (37).

The existing form of the Appalachians is due to carving of this complex mass by Cenozoic erosion. It is uncertain how far inland the Cretaceous Atlantic Coastal Plain extended; this extent being indicated only by certain characteristics of the pattern of some of the streams. If the Cretaceous beds were ever present they were stripped away during a long period of peneplation. The Schooley peneplain was the flat surface then formed (37). It is the oldest surviving peneplain not preserved by burial (12).

The Blue Ridge Province extends over seven hundred miles from Alabama to Pennsylvania (37). Most of the rocks are old, strong, and of highly complex structure, representing an ancient land mass repeatedly raised into mountains and continuously eroded. This was during the Paleozoic time when the newer Appalachians were non-existent. The western front of the range is on lower Cambrian quartzites which were raised into mountains in the Appalachian revolution when the mountains and plateaus farther west were formed. The rocks of this Blue Ridge province are highly metamorphosed and without great difference in hardness, all being of Cambrian origin, consisting of strong conglomerate, quartzite, slate, and schist with some less-altered beds (12).

The southern section of the Blue Ridge Province extends southwestward from Roanoke Gap with a maximum breadth of seventy miles (12). The Flat Rock area, being in the vicinity of Grandfather Mountain, lies near the 36th parallel, present drainage radiating from this locality. The highest peneplain level is 3,800 to 4,000 feet, which is 2,500 feet above the Piedmont plain. The surface of Grandfather Mountain is on a fault block of Cambrian quartzite (12).

Flat Rock is a large outcrop of quartzite with ribbons of white quartzite running through it. Quartzites, formed by the metamorphism of sandstone, are among the hardest and most resistant of all rocks. Quartz grains are about the same regardless of temperature, therefore, little change can take place in them. They are so tightly cemented together that in fracture the grains do not separate but break right through (33).

Millions of years have been required to break down the rocks of the mountains of this region to form a blanket of soil. These mountains were never exposed to the glaciers of prehistoric times.

II. PHYSIOGRAPHIC

Exposure and Slope

Various factors of the environment affect the vegetation of an area and determine the community structure. Two vital factors in the Flat Rock area are exposure and slope. Figures 2 and 3 reveal the steepness of the slope on the western boundary of the rock.

Exposure, such as the position of a slope in relation to the sun, affects humidity through the influence of the sun and wind. Maximum effectiveness of insolation results

FIGURE 2

STEEPNESS OF SLOPE AT FLAT ROCK

FIGURE 3

STEEPNESS OF SLOPE AT FLAT ROCK

when it strikes a surface at right angles, therefore, the greater the variation from a ninety-degree angle, the less radiant energy will strike a unit area (30).

Altitude

The altitude of the Flat Rock area ranges from 4,200 feet on the rock to 3,900 feet on the eastern boundary at the parking area.

III. CLIMATIC

Temperature and Growing Season

The effect of temperature on plant life is obvious when the vegetation of the tropical region is compared with that of the arctic regions. A narrow temperature scale is responsible for these variations. In general, plants are adapted to temperatures ranging from 0° to 50° C.

Forest cover in general reduces the maximum temperatures and raises minima throughout the year and reduces the range of temperature, annual, monthly, or diurnal. The temperature effects of the forest vary in different localities and with the character and density of the cover (22).

The mean annual temperature is the most important temperature factor for determining the general character of the vegetation. No data could be secured on the Flat Rock area itself, however, the mean annual temperature for the whole of

Avery County was 53.95°F over a period of thirty-one years (44). The maximum recorded for Avery County was 95°F and the minimum -21°F. The average temperature which has been recorded for the month of January was 34.4°F and 66.4°F for the month of July. The average date for the last killing frost in the spring was May 11, while the average date for the first killing frost in the fall was October 6. The average growing season was 148 days.

Precipitation

Moisture is the entire force which activates the nutrients of the soil and makes them available to plants. More than any other factor of the habitat, moisture affects the morphology of the plant organs that determine the physiognomy of vegetation. Generally, moisture causes the divisions within the vegetational zones of the earth due to temperature. It determines the structure and arrangement of plant communities. Moisture is determined by the amount, duration, and seasonal distribution of the precipitation and by the humidity of the air. Precipitation may be in the form of rain, snow, frost, dew, sleet, or hail. Next to temperature the annual distribution of rain is the most important factor for the general character and periodicity of vegetation (3).

There are several factors which determine the usefulness of precipitation to plants. Aside from the intensity of the precipitation, the character and condition of the soil and the nature of the topography are important factors governing the proportion of water lost and thereby determining its usefulness to plants. There are five major features of the earth's surface which are important in this respect: (1) moisture content of the soil, (2) soil temperature, (3) porosity, (4) smoothness of slope, and (5) steepness of slope (9). These characteristics exhibited at Flat Rock have provided for xerophytic vegetation on the western boundary of the rock to a mesophytic forest on the eastern boundary.

Figures for Avery County show the average annual precipitation to be 53.95 inches. The month of the highest average precipitation is July with 6.58 inches, while the lowest is November with an average of 2.98 inches (44).

Wind

Finnell (1928) studied the effects of wind on marigolds at the Panhandle Agricultural Experiment Station, Goodwell, Oklahoma (52). These plants were exposed continuously for sixty days to wind velocity of approximately fifteen miles per hour. The experiment showed that portions of tender foliage were actually destroyed by wind and whipping, and there was a marked deformation of the main stem in early growth stages. As measured by the height of the plant, the rate of growth was immediately reduced. In a sixty-day drowing period the time of maturity was increased about ten days. The wind reduced the yield of dry matter 48.8 per cent. The total water requirements per pot did not vary significantly, but the water requirements per unit of dry matter produced were approximately doubled by exposure of the plant to the wind. The number of secondary branches formed was apparently increased 42.8 per cent.

Wind is an ecologic factor of considerable importance, especially at high altitudes in the mountains. It affects the plants directly by increasing transpiration and causing various kinds of mechanical damage. Less direct effects include the transportation of hot and cold masses of air and moving clouds and fog that change water relations and alter lighting conditions (9).

In the Flat Rock area dwarfing and deformation or wind training are displayed in the trees of the western boundary along the border of the rock. Figure 4 shows evidence of dwarfing, in which the maturing cells have not expanded to normal size. When young shoots are subjected to strong wind pressure from a constant direction, the structure and position of the shoot may become permanently altered. Figure 5 shows the response of the vegetation to the constant winds, thus, producing deformation. The tree branches have developed only in a leeward direction.

There is another great influence of wind upon the

FIGURE 4

DWARFING DUE TO WIND

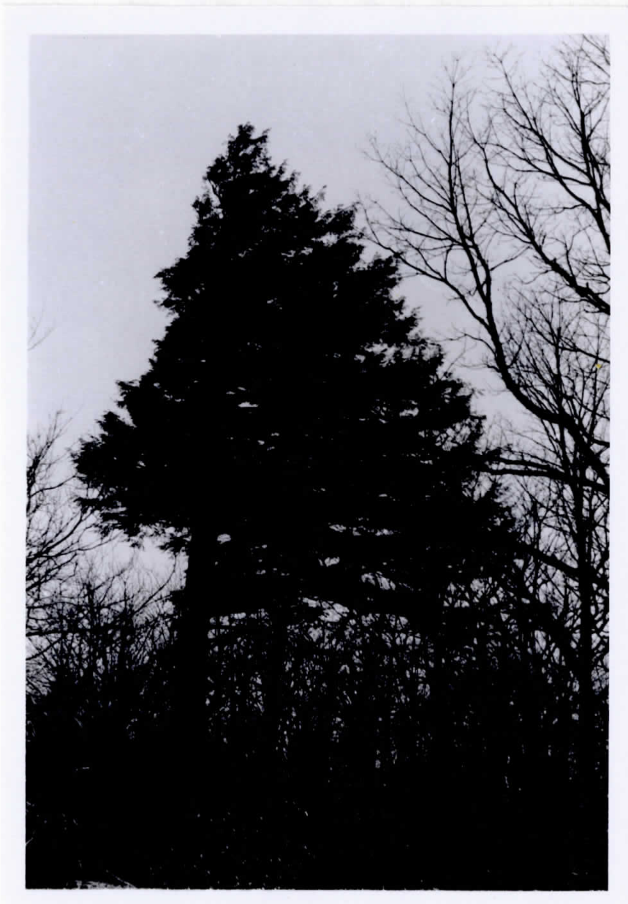

FIGURE 5

DEFORMATION DUE TO WIND

vegetation of an area. The wind not only carries spores, pollen, and many kinds of seeds to new locations, but also plays a distinct role in the development of communities. The vegetation of habitats exposed to wind is totally different from that of protected habitats. Some plants are much more resistant than others to the effects of wind. Studies of Flat Rock demonstrate this factor. Prevailing winds are from the northwest and blow almost constantly across the rock, and during the winter with severe force. *Pinus rigida* Mill. was found growing along the eastern boundary of the rock and no other place in the forest of the Flat Rock area. Other wind-resistant plants growing along the eastern edge of the rock were *Gaylussacia baccata* (Wang.) K. Koch.

Wind loses its velocity upon encountering a forest, and studies show that it retains only sixty to eighty per cent of its original force after penetrating a distance of some one hundred feet, if the forest is dense. At a distance of about two hundred feet it has only fifty per cent of its force, and at four hundred feet only seven per cent (47).

Atmospheric Pressure

Experiments have shown that a decrease in atmospheric pressure, other conditions remaining the same, is accompanied by increased growth in plants. There is no experimental data to indicate whether the normal atmospheric pressure is at the ecological optimum for the sum total of the plant's activities. A decrease in atmospheric pressure increases the relative humidity of the air and, consequently, tends to check transpiration. At higher altitudes the pressure is decreased but is ordinarily more than counterbalanced by the decrease in temperature, which has the opposite effect on humidity. Altogether the atmospheric pressure is not of great importance from an ecological standpoint (25).

IV. EDAPHIC

Soil Structure

Rock is directly responsible for the overlying soil and hence for its vegetation. Rocks not only differ as to the character of their vegetation, but new "species" are developed in various rock habitats (51).

The German botanist Unger in 1836 published a paper on soil influences, this being one of the first outlooks into the field of plant ecology (51). His attention was centered upon the differences between plants of siliceous and calcareous soils. This, he explained, was due to the chemical relations of the soil to the plants; what was foodstuff for one plant was poison for another. A large number of species were found to be indifferent.

In contrast with Unger's theory is the physical theory which Thurmann proposed in 1849 (51). He regarded the soil structure as more important than soil chemistry. This is especially true since the physical structure of the soil largely determines the water and heat relations.

Warming (1895) summed up both conflicts, acknowledging the truth in each, and concluded that the physical theory was quantitatively more important because of its influence on the water relation of the soil (51). It was he who classified plant societies into three main groups: (1) hydrophytes, (2) mesophytes, and (3) xerophytes. In the fourth group, the halophytes, he recognizes the dominance of chemical influences.

Other factors which must be considered are: (1) the line between chemical and physical influences cannot be drawn, (2) the struggle for existence, (3) the relation between the rock and soil which comes from it, and (4) the physiographic or historical factor. Regardless of the type of rock the initial plants and conditions will be much the same and the ultimate plants and conditions exactly the same. Exposed rocks of all kinds have much the same floras. The ultimate common destiny is the mesophyte forest (51).

Soil plays an important role in controlling the development of the types of communities. As a result of the control which soil exercises over the habitat, a community may remain for a long time at a particular stage of development (10).

Reed (1905) described the general soil conditions of the 16,000 acres, which were then a part of Caldwell, Mitchell, and Watauga Counties (57). Flat Rock was included in this area. The soil was very thin or entirely wanting on the upper slopes and tops of the higher mountains, occurring only in patches in crevices between the rocks. Lower down the soil gradually became deeper and was generally described as fined-grained loam. The soil was apt to be sandy, mixed with small quartz pebbles or sandstone, quartzite, and conglomerate.

The soil of the Flat Rock area is relatively thin in close proximity to the rock. However, toward the eastern boundary the soil becomes progressively deeper, except where there is an outcropping of rock of the same composition as that of Flat Rock.

According to the Atlas of American Agriculture (45), the soil in the Flat Rock area is of the Chester type. The Chester soils have developed from material accumulated by decomposition in place of crystalline schists and gneisses, having the well developed color and texture profile of the Gray-Brown Podzolic group. The Chester loam is classified as being of the order of Pedalfus or zonal soils. The sub-order is light-colored podzolized soils of the timbered region. This is further classified into the Gray-Brown Podzolic soils, Chester being the family, as well as the Series and Type (43). The Chester soils are generally less acid than Podzols and are characterized by a thin leaf litter over dark-colored surface soil. This is two to four inches thick over grayish-brown leached horizon over brown heavy B horizon. The pH of a sample of soil taken from the Flat Rock area was found to be 6.0. The typical vegetation of this type of soil is mostly deciduous forests mixed with conifers in places.

Biotic

No plant or animal is a completely independent organism. Some plants may depend upon others for shade, while other plants depend upon insects for pollination. All plants are considerably influenced by other organisms in ways which may not always be obvious. The amount of moisture, heat, light, and nutrients which a plant receives are all determined by the proximity of other plants.

In any forest, plants serve as a source of food for many animals. Other animals help to distribute pollen or seeds and their activities tend to check and balance the entire community. However, in no way does any animal control the entire community that is dominated by the plant species. The animal is only of secondary importance.

A record of animal life was kept during an eight-month period of the Flat Rock area. While the purpose of the study was not the search and identification of all the animals in the area, such animals observed were recorded. In some cases the observation was limited to the identification of the scat, or to the odor, as in the case of the skunk. Appendix A shows the different animals and birds which were observed during the investigation of the area.

Fire is another biotic factor of tremendous importance, and one which is particularly destructive on thin soils. In the Flat Rock area several trees at various places show evidence of fire, which apparently occurred many years ago. It is impossible to know the exact influence this had upon plant succession at Flat Rock. Nor is it possible to know of the extent of the fire in the area. The original vegetation may have been partially or entirely destroyed, therefore, it is a secondary succession.

The human agency is a biotic factor of extreme importance. The study made by Reed (57) was done for the purposes of lumbering the area, but it is not known if lumbering was actually done at Flat Rock or not. A few very old stumps were found at various places, which may be evidence that commercial lumbering was done at that time.

CHAPTER IV

SUCCESSIONAL RELATIONSHIPS

Oosting has recognized several kinds of succession (30). Primary succession is initiated on a bare area where there has been no previous vegetation. These habitats are likely to be unsuitable for growth of most plants, consequently, the pioneer plants are capable of adapting to adverse conditions in order to survive. Secondary succession results when the normal succession is disrupted by any condition which destroys it, such as fire, flood, or lumbering.

> Because water and bare rock represent the extremes in types of habitats which succession is initiated, the growth form of early stages of each is remarkably similar everywhere and even genera and some species are often duplicated regardless of the region. (30, p. 214)

A successional series is sometimes called a sere. The sere always starts on a bare area and is either wetter or drier than the habitat of the climax association. If the bare area is drier than the climax the succession progresses from xeric toward mesic and is termed a xerarch. A sere that has its origin in bare rock is called a lithosere (25).

Xerarch succession on rock is a process which is not fully realized in a single growing season, but one which may take many years, or even centuries. The pioneer mosses and lichens are capable of chemically breaking down the rock into soil and building enough to hold some moisture. The rate at which the soil forms and accumulates determines the rate of succession. The lichens do not contribute as much to the succession as do the pioneer mosses which catch dust and minerals from wind and water.

The rapidity with which soil is formed is controlled largely by the nature of the rock and by the climate. The crustose lichen stage might persist for centuries on quartzite or basalt if the climate is dry. But invasion of foliose lichens may occur within a lifetime on limestone or sandstone if the climate is moist (41).

Only a small amount of soil is required for the mosses to grow along with the lichens. The species of plants which move in as the succession takes place depend upon the surrounding communities which supply the seeds.

The saxicolous community, as defined by Smith (38), is composed of rock-lichens. Rocks which weather or erode at a rapid rate are almost entirely bare of lichens, the reason being that the disintegration of the surface gives no time for the formation of the thallus or the fruit. Quartzite and other close grained rocks have poor lichen flora, as the rooting hyphae are unable to penetrate and grasp the rock. This statement may be generally true, but it is contradictory to the findings of the Flat Rock area.

Crustose lichens are the pioneers in the xerarch succession, for they alone are able to survive such adverse conditions. They flourish when there is sufficient moisture and become dessicated during periods of drought. They may remain in this state almost indefinitely.

Findings of Previous Studies

Linnaeus (1762) described the succession of plants, pointing out that ". . . . crustaceous lichens are the first foundation of vegetation. . . ." (38, p. 392). Goeppert (1860) designated Parmelia saxatilis, Parmelia stygia, and Parmelia encausta, which are foliose species, as special rock destroyers. Crustaceous species Lecanora polytropa and Candelariella vitellina exercise an equally powerful solvent action (38).

Cowles (1901) studied the flora of granitic rocks in the Lake Superior region and in Connecticut (51). He found the first plants to get a foothold were the crustose lichens. The lichens come early because the erosion is differentiated and stay late because the erosion is slow.

Cooper (1912) found three subsuccessions in his investigation of the ecological succession of mosses on Isle Royale (50). The most abundant moss growing on the bare rock surface at the lower edge of the crustose lichen zone was Grimmia ovata Web. and Mohr. Orthotrichum anomalum Hedw., the most common one a little higher up, was accompanied by Hedwigia albicans (Web.) Lindb. In the zone above, Grimmia and Orthotrichum had lost their dominance to foliose lichens and Hedwigia. Fruticose lichens were dominant in the third lichen zone.

Mosses were of little importance in the crevice subsuccession of Isle Royale. The commonest species occurring as crevice plants were Polytrichum juniperinum Willd. and Parmelia piliferum Schreb. The commonest moss which appeared in sheltered crevices was Swartzia montana (Lamk.) Lindb. Mosses were frequently absent in the rock-pool subsuccession.

The three subsuccessions united in the formation of a heath mat at Isle Royale. Most important of this stage were Thuidium abietinum and Calliergon Schreberi (Willd.) Grout, which were accompanied by tangles of Juniperus horizontalis, Juniperus communis var. depressa and Arctostaphylos Uva-ursi.

The climax forest of Isle Royale was controlled by balsam fir, paper birch, and white spruce, while the undergrowth was composed largely of Calliergon, Hylocomium, and Hypnum.

Cooper (1913) noted a marked correspondence between the conifer forest of the southern Appalachian summits and the Isle Royale forest, indicating that the forest dynamics were essentially the same (49). However, the rocks of Isle Royale are partly volcanic with lesser amounts of sandstone and conglomerates.

In the study of Isle Royale, Cooper found a thick coating of lichens on the smooth cliffs rising above the water, the most conspicuous one being the brilliant orange Placodium (49). On the sandstone cliffs, which were being rapidly eroded by waves, lichens were absent. At least nine-tenths of the forest of Isle Royale had developed along the line of xerarch succession.

Cooper distinguished three separate lines of advance in early stages of rock shore succession, which he termed subsuccessions. In the rock surface subsuccession the lichens appeared first and were accompanied by Grimmia ovata Web. and Moore. Placodium was the prominent feature of the cliffs. The foliose lichens then appeared with the mosses Hedwigia albicans (Web.) Lindb. and Orthotrichum anomalum Hedw. Finally appeared the fruticose forms, prominent among them Cladonia rangiferina (C.) Web., Cladonia sylvatica (C.) Hoffm., and Cladonia alpestris L., which also composed the mats. The pioneer of the mats was Rhacomitrium.

The crevice subsuccession was a natural collecting place for seeds carried by wind, birds, and surface wash. Cooper found one hundred species, or one-fifth of the recorded flora of Isle Royale, growing in crevices on the rock shores. The climax forest was very much hastened through the soil and moisture conserving capacity of the crevices, resulting in abundance and variety of creeping mat-forming shrubs.

The rockpool subsuccession was less important than the two preceding ones. Rain and waves supplied the water, which was often only temporarily present. Vegetation was of the crevice type in the smaller depressions which contained water only part of the time.

The fourth stage which Cooper found at Isle Royale was the heath mat. The succession here was from Potentilla tridentata and Deschampsia caespitosa to Arctostaphylos, Aralia nudicaulis and Maianthemum canadense.

The jack pine-black spruce stage was the climax forest which followed immediately after the establishment of the heath mat. In many places a xerophytic forest stage intervened with the species Pinus Banksiana Lamb. and Picea mariana (Mill) BSP. The conditions which caused the presence or the absence of this stage were not discovered by Cooper. In the jack pine-black spruce forest where the conditions were most xerophytic Pinus Banksiana was dominant. The evidence derived indicated the forest will gradually become more mesophytic in character as the vegetation of the forest floor increases in amount and in water-holding capacity.

In concluding his investigation of Isle Royale, Cooper found the lower limit of possible forest extension was determined approximately by the upper limit of effective wave and ice work, providing the lake level remained constant. The present extent to which the forestable territory has been occupied depends upon the rapidity of invasion, this being governed by the character of the rock, the angle of the slope, and the degree of exposure to the winds. These factors resulted in three phases of rock shore vegetation — the climax forest to the water's edge, a zone of incomplete invasion, and abrupt transition from the bare rock shore to climax forest (49).

Braun (1917) studied successive colonization of limestone conglomerate and found the crustaceous lichens Lecidea sp., Pertusaria communis, Staurothele umbrina, Verrucaria muralis, and Placodium citrinum were the first to gain a foothold. Associated with these were small quantities of the moss Grimmia apocarpa. The most prominent plants of the second stage of growth were Dermatocarpon miniatum and Omphalaria sp. with the next stage consisting almost exclusively of mosses and hepatics with Peltigera canina (49).

Taylor's study (1920) of the Carrol Creek region revealed liverworts to be the first plants in the very moist places (58). Above the liverwort zone were found crustose lichens, these being followed by foliose forms. Grimmia apocarpa was the first moss, which was accompanied by Bryum argenteum. Second and third moss stages were common. In sunny places Bryum argenteum formed the second stage with some Hypnaceae as the third vertical layer.

Taylor found a small quantity of liverworts with an extensive growth of crustose lichens on the shaded vertical face. On the upper surface the crustose lichens were being overgrown by foliose lichens. In shady places along a creek

Anomodon formed the moss stage following the pioneer lichens. In some places the cliffs were covered with _Juniperus virginiana_ and deciduous trees and shrubs. On vertical surfaces, in well shaded moist places, were found masses of _Anomodon viticulosus_ (58).

Oosting and Anderson (1937) observed the stages in development from bare rock pioneers to woody species (56). They found small plants of _Rhacomitrium heterostichum_ (Hedw.) Brid. var. _ramulosum_ (Lindb.) G. N. Jones and _Andreaea rupestris_ Hedw. growing in minute crevices of the rock not previously occupied by any visible sign of crustose lichens. Once a colony of _Rhacomitrium_ or _Andreaea_ was established it slowly spread on the bare rock in a circular fashion. When the moss mat came in contact with scattered lichens and other mosses they were engulfed and eliminated.

Their study showed that definite mats began when _Cladonia subcariosa_ Nyl. and _Cladonia coccifera_ (L.) Willd. invaded either _Rhacomitrium_ or _Andreaea_. After these had gained sufficient foothold, the patch increased in thickness and additional species of larger cladonias appeared. The stages of development of most mats could be determined by dissecting them.

After the mat had built up to several inches the first woody plant to appear was _Chionanthus virginica_ L. Later the seedlings of _Acer rubrum_ L. gained a foothold. Oosting and

Anderson found that Juniperus virginiana L. often germinates on the mat but rarely lives to reach much size. All the woody plants which start do not survive, and growth is very slow for those which do survive. Chionanthus and Acer, which occur in mats that have been established for some time, are relatively stable and tend to maintain their position indefinitely. A transect on an older mat showed the complete successional series from Andreaea and Rhacomitrium.

This study by Oosting and Anderson (56) showed the dominant tree species in the forest on the old mats were Tsuga canadensis (L.) Carr., Juniperus virginiana L., and Pinus strobus L., which were all undersized. Their growth had been very slow and increment borings showed irregularities in rates of growth. The undergrowth on these mats was made up of Rhododendron catawbiense Michx. and Kalmia latifolia L. The surrounding forest was predominately oak-chestnut.

Oosting and Anderson (1939) in their second study distinguished two surface variations which determine succession upon bare rock: (1) the dry bare rock surface in general, and (2) the depressions below the level of the surface proper (55). They found that the earliest pioneers were the same on every rock area studied, regardless of the rock surface. The regular pioneer mat former was Grimmia laevigata (Brid.) Brid. Its habitation was not restricted to areas occupied by crustose lichens. Probably the first plant occupants were crustose lichens, such as Verrucaria nigrescens Pers. and the foliose lichen Parmelia conspersa (Ehrh.) Ach. These were of no importance in the succession because of their accumulation of such a small amount of soil. Diamorpha cymosa (Nutt.) Britton is often associated with Grimmia but it is relatively unimportant in the development of mats. Grimmia grows only on sunny, dry, well drained surfaces, therefore, cannot initiate succession along woody margins.

Oosting and Anderson found no mats which supported more than a few species of tree size. The larger specimens were always inferior. Twenty-five years was the average age of the larger trees on the mats. There are many factors which restrict the development of substantial anchorage. As growth takes place they become more susceptible to wind-throw. When a tree is upturned, its roots dislodge and remove the mat. Fire also restricts further development of older mats. Oosting and Anderson found every outcrop had evidence of recent fire. Erosion is another factor in explaining why these particular eastern outcrops are barren. These factors are in contrast with the outcrop of western North Carolina where the slopes are much steeper and the weights of the mats release their hold.

The eastern and western exposures of the areas studied by Oosting and Anderson are roughly in the same latitude but there is a difference of some 3,000 feet in altitude. This difference results in a shorter growing season in the mountains, temperatures are lower, with complete dessication rare. Despite these differences the successional relationships are very similar.

In summarizing their study (55), Oosting and Anderson found the granite rock in eastern North Carolina was an unfavorable habitat for plant colonization, particularly so because of the long dry summers with high temperatures. Succession on the rock followed two major lines, originating, first, anywhere on the rock surface and, second, in depressions. The bare rock surface was invaded by Grimmia or crustose lichens, the latter not contributing to further succession. Grimmia formed mats which were successively invaded by four stages dominated by Cladonia, Selaginella, Polytrichum, Andropogon, and conifers.

The study of Rocky Face Mountain, done by Keever, Oosting, and Anderson in 1951 (54), shows the eastern, southern, and western sides present the same kind of situation and have the same types of vegetation and mat development. The succession usually starts on bare rock. Occasionally it is initiated on thin layers of sandy soil accumulating in shallow depressions. These two lines of succession differ tremendously in the beginning stages, but eventually lead to the same type of mat.

Staurothele diffractella (Nyl.) Tuck was the pioneer of the bare rock phase. It is a crustose lichen which is able to withstand dessication and grow without soil. Peccania kansana (Tuck.) Forss. is a brown crustose lichen found on rough or damp surfaces. There was no evidence that these lichens were corrosive enough to have been a factor in permitting other plants to have followed. Grimmia laevigata (Brid.) Brid. was the first pioneer which showed definite evidence of contributing to soil building and succession.

In the thin soil phase of Rocky Face the moisture conditions varied widely. The pioneers were the vascular plants Diamorpha cymosa and Talinum teretifolium. Their only contribution was to keep sand from washing, since they did not contribute to mat building. Cladonia, Campylopus, and Opuntia were considered the mat builders. Succession was accelerated when these were present, but it might have proceeded without them. The next plant of importance in the succession was Polytrichum commune Hedw., this being true whether lichens were present or absent.

Often there was no shrub stage on the sunny slopes of Rocky Face and trees immediately followed the herbs. The first woody plants to invade were Juniperus virginiana and Pinus virginiana. The rate of growth of the woody plants decreases as moisture requirements become greater.

The comparison of sunny and shady exposures of Rocky Face showed considerable difference in the dominant species of the two slopes, but the pattern of successional development was the same.

The comparison of Rocky Face with the other North Carolina outcrops studied showed, in every instance, first plants to appear were crustose and foliose lichens, but were not found to be essential to further plant development on any outcrop. Mosses were the pioneers which initiated succession, these followed in turn by herbs, shrubs, and trees. Species comprising these stages differed in the three localities. Parmelia conspersa, Cladonia tenuis, and Juniperus virginiana were the only species found in all three situations. Some species of Polytrichum were found in each locality.

It is apparent that only a limited number of growth forms are adapted to become established on rock surfaces. The pattern in which these forms succeed each other is constant (54).

In plant succession the foliose-lichen stage usually appears as soon as a little soil has accumulated, these forms slowly replacing the crustose forms. The humus which accumulates from the decaying crustose species prepares the way for a new invader which soon begins to appear with the foliose lichens. The xerophytic mosses which move in have as much power of withstanding dessication as the lichens. Sometimes the mosses may precede the foliose lichens (41).

Seed plants appear on the moss-lichen mats after the soil has built up sufficiently to provide necessary anchorage and moisture. This is comprised first of short lived annuals with biennels and perennials invading later, of which grasses are most abundant. As the humus accumulates the soil becomes more moist, evaporation and temperature variations are decreased and the conditions become less xeric.

Each successive stage in the xerosere plays a larger part in the process of succession. The decay of each generation adds more organic material until finally a uniform soil is constituted. Later the shrub stage becomes dominant, generally including species of Rhus and Ericaceae. Some shrubs may start from seed while others may invade from adjacent areas by rhizomes. The invasion of the shrubs usually brings tangled growth and dense covering, which results in the disappearance of herbaceous growth.

Even though the soil at this stage is several inches thick and relatively rich, the first species of trees in the climax forest are somewhat xeric (41). As the soil deepens the trees increase in number and strength. The type of climax forest eventually reached depends not only upon the surrounding community, but is even more dependent upon climatic factors.

CHAPTER V

ECOLOGICAL STRUCTURE OF FLAT ROCK

The foregoing review of previous studies and other pertinent factors served as a background for the field work done at Flat Rock. This field work produced the raw material which has been organized and arranged in tabular form and presented in this chapter along with a discussion of the data. A discussion of the communities found on the rock is presented first, this being followed by a discussion of the forested area surrounding the rock.

Studies of the Vegetation on the Rock

Quadrat # 1 was located in the northern portion of the rock near the path. The vegetation in this area is under the influence of a continuous wind along the fringe of the woods. The exposed rock supported growths of the crustose lichen Lecanora atra (Huds.) Ach. and the foliose lichen Umbilicaria pustulata (L.) Hoffm. See Figure 1, page 9, for the location of the quadrat. See Figure 6 for a description.

The thin soil area along the margin of the woods supported extensive growth of Galax aphylla (L.), Gaylussacia baccata (Wang.) K. Koch, Gaultheria procumbens L., Rhododendron catawbiense Michx., and a few grasses. Throughout much of this fringe area were mats of Selaginella rupestris (L.) and

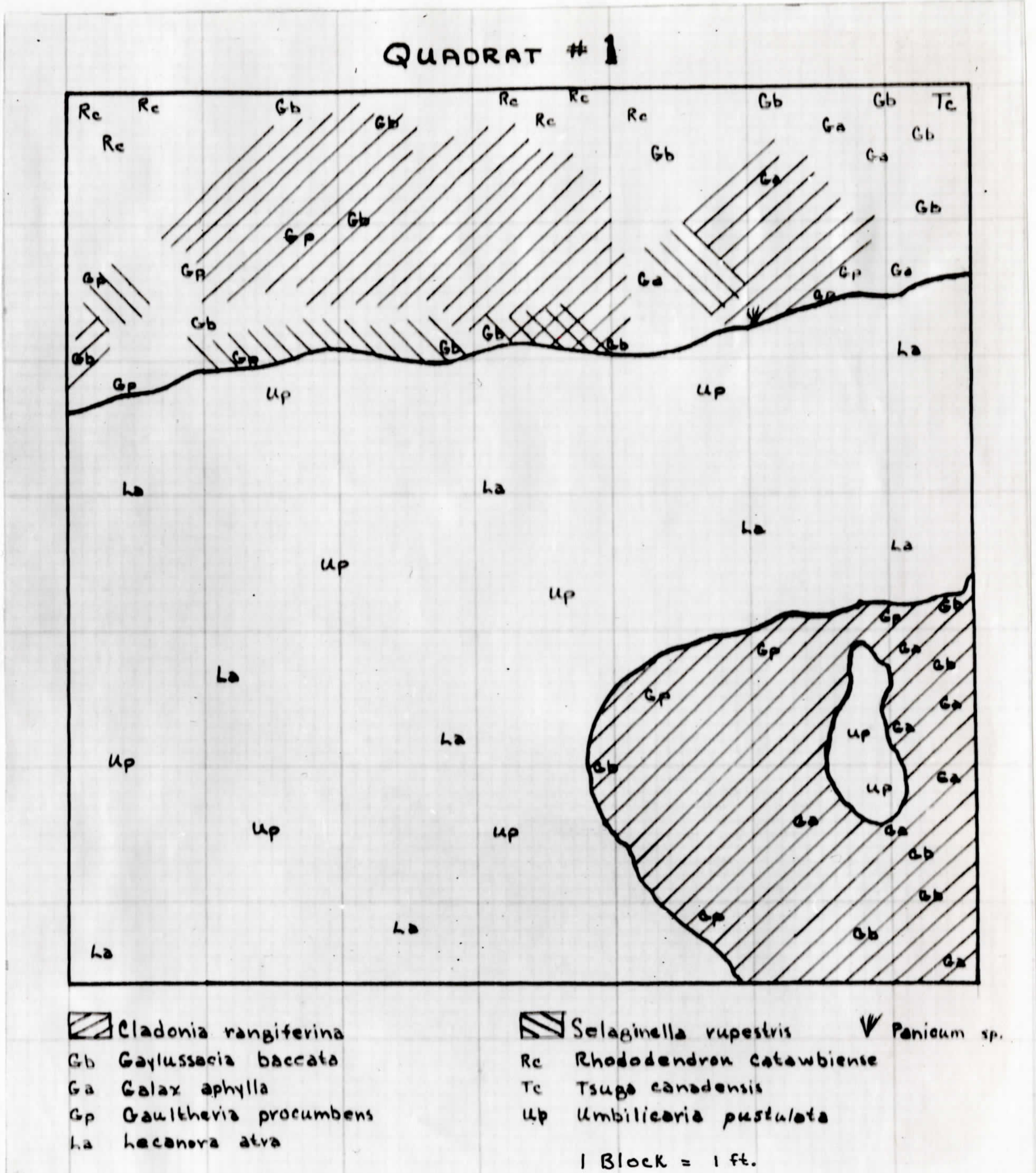

FIGURE 6

QUADRAT # 1 ON FLAT ROCK

Cladonia rangiferina (L.) Web.

In one corner of the quadrat was a stunted and deformed Tsuga canadensis (L.) Carr. The diameter breast high was less than one inch and the height was five feet. Its age was not determined.

Quadrat # 2 was located on the western slope in the central portion of the rock. See Figure 1, page 9. Thick mats of Selaginella rupestris and Cladonia rangiferina left very little exposed rock. Several specimens of Cladonia pyxidata (L.) Hoffm., Cladonia cristatella Tuck., and Usnea barbata (L.) Wigg. were found growing in the clumps. Several small plants of Gaylussacia baccata and Gaultheria procumbens, along with the fern Polypodium vulgare L., were growing in the mats. The mosses growing in this quadrat were Polytrichum commune L. and Grimmia apocarpa (L.) Hedw.

Exposed areas of the rock supported growth of the crustose lichens Lecanora atra and Lecanora versicolor (Pers.) Ach. along with the foliose lichens Parmelia conspersa (Ehrh.) and Umbilicaria pustulata. One clump of grass had moved into a crevice in the rock. This area was partially shaded by a Pinus rigida Mill. growing on the rock on the slope above it and by several plants of Kalmia latifolia L. growing along the side of it. See Figure 7 for a more detailed description of this area.

Quadrat # 3 was located on the southern portion of the

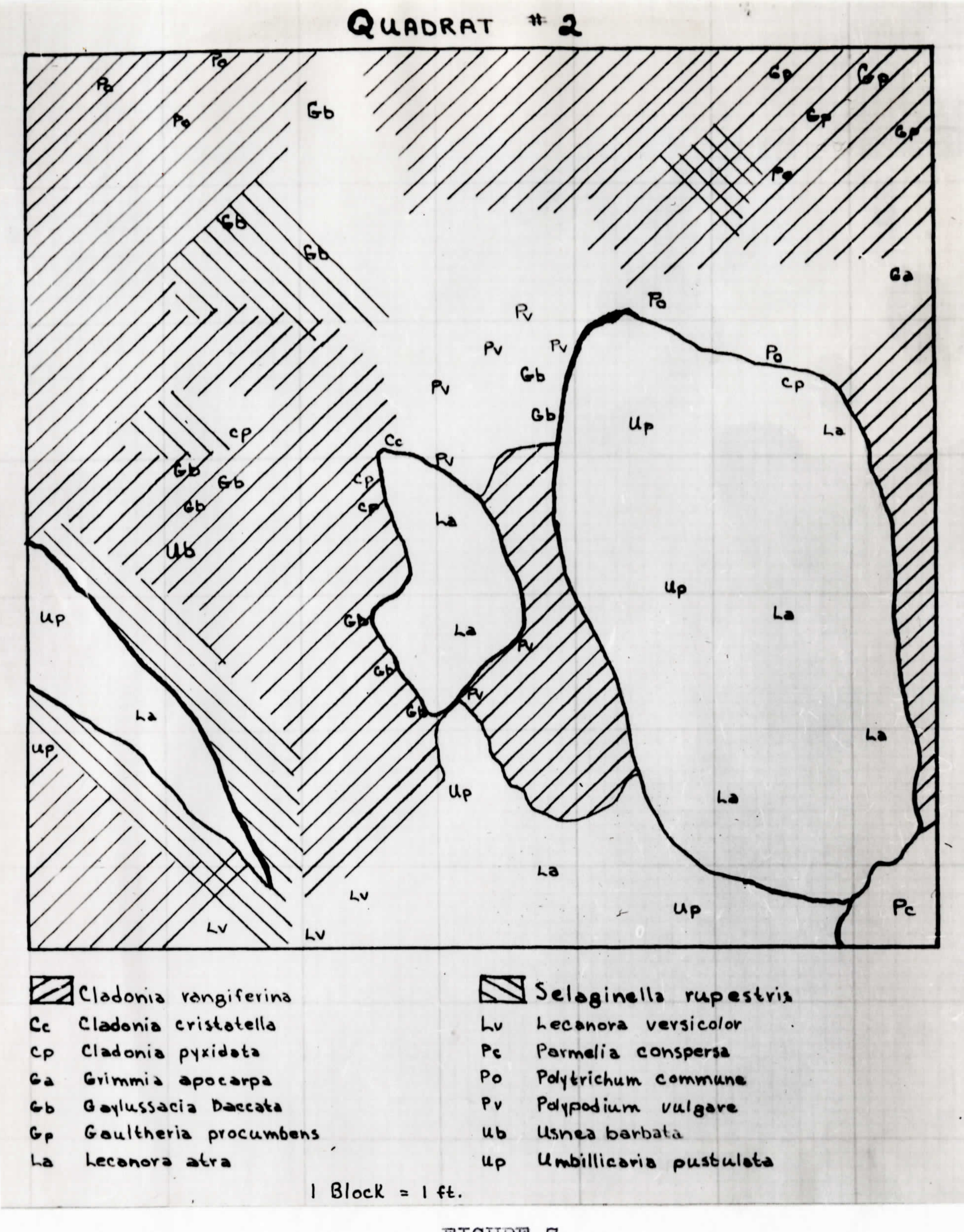

FIGURE 7

QUADRAT # 2 ON FLAT ROCK

rock about ten feet from the western edge. See Figure 1, page 9. In one corner of the quadrat, where there was a thin layer of soil, a dwarfed clump of Quercus alba L. was growing. The diameter breast high of the largest one was 2.5 inches and its height was approximately twelve feet. Borings showed the tree to be twenty-five years old.

The exposed portions of the rock in this section were supporting extensive growth of the lichens Parmelia conspersa, Umbilicaria pulustata, Caloplaca elegans (Link.) T. Fries, and Lecanora atra. There were a few specimens of the lichens Physica stellaris (L.) Nyl., Cladonia pyxidata, and Usnea florida (L.) Web., and the club moss Selaginella apoda (L.) Fern. There was one specimen of Polypodium vulgare. Several species of the crustose lichen Lecanora were present but were not identified by the writer. A few crevices in the rock supported several plants of Selaginella rupestris and Cladonia rangiferina.

The matted area was composed of very thick clumps of Cladonia rangiferina and Selaginella rupestris. These were growing entangled in several sections, but it appeared that the Selaginella was growing on the patch of Cladonia. Grasses had moved in on the clumps and were gaining a foothold along the edge of the rock. Intermingled with the Selaginella and Cladonia were patches of Grimmia and Bryum caespiticium L. For a more detailed description of the quadrat see Figure 8.

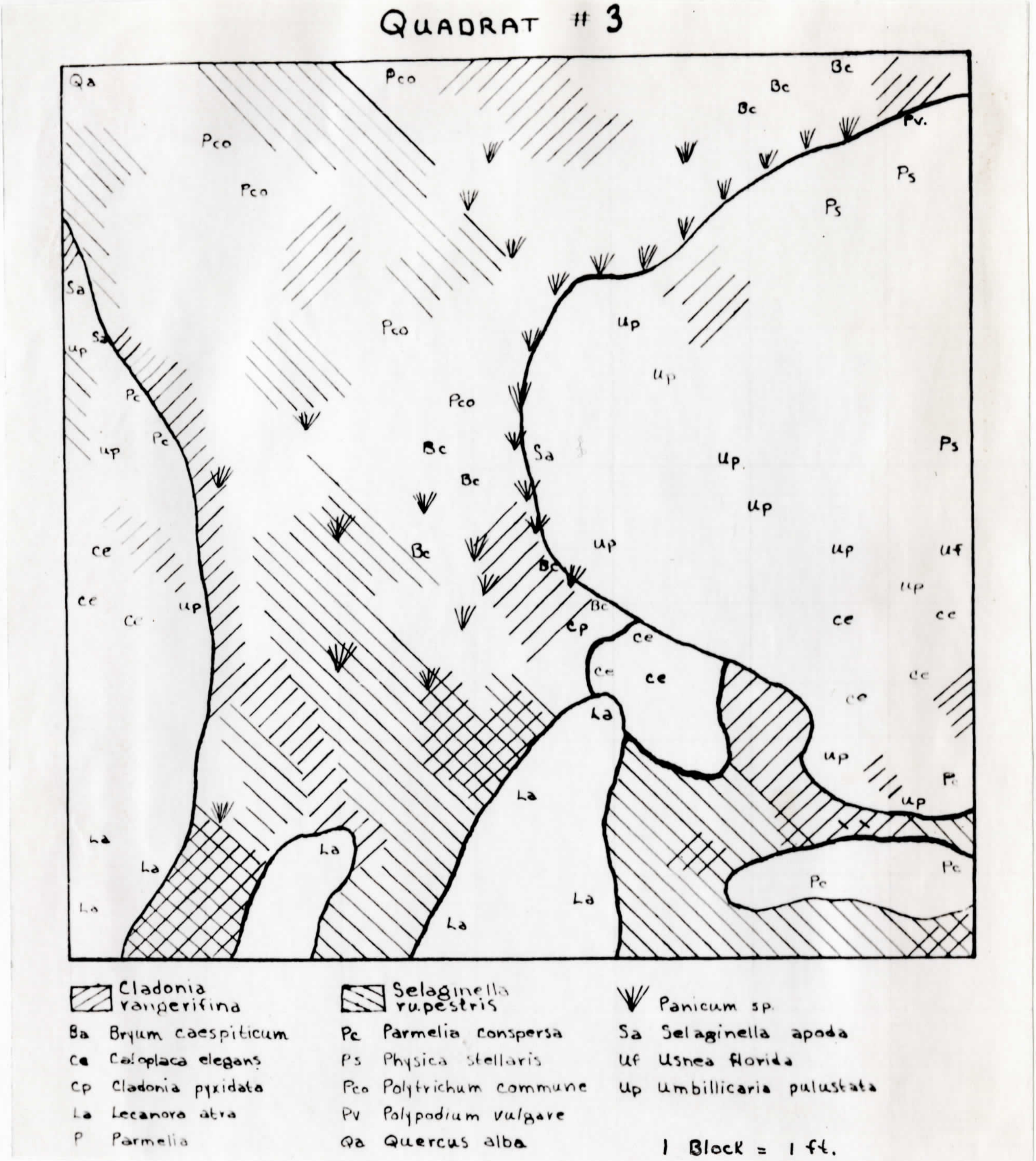

FIGURE 8

QUADRAT # 3 ON FLAT ROCK

The area outside the quadrats was essentially the same as that within the quadrats. Scattered throughout the entire rock were rock pool subsuccessions which supported several species of crustose lichens. Figure 9 is an example of one of the more permanent pools on the rock, but one which dries up after several weeks without rain.

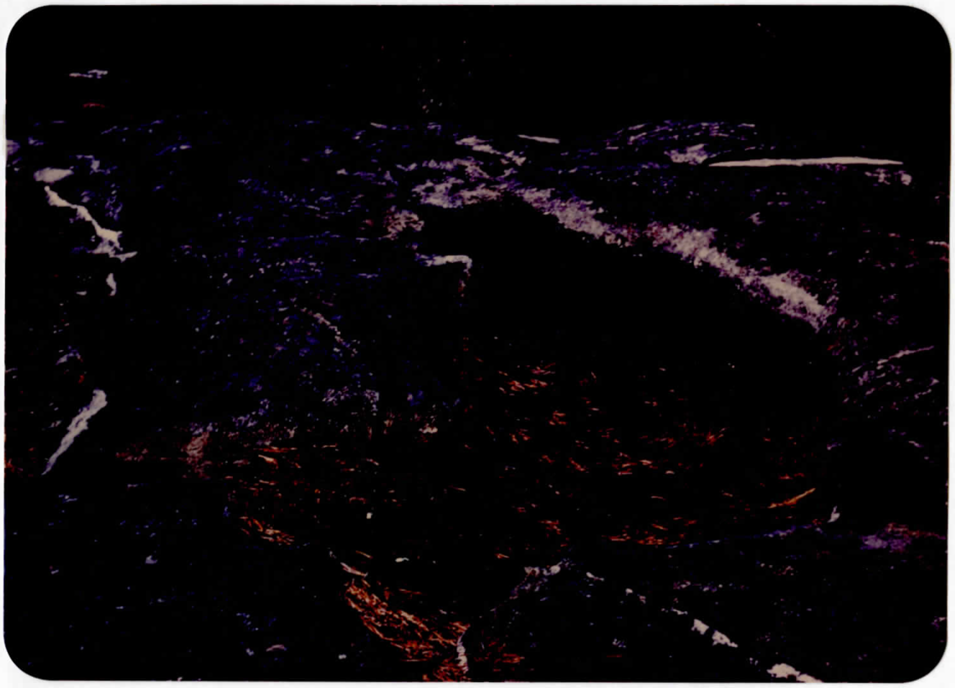

FIGURE 9

ROCK POOL SUBSUCCESSION ON FLAT ROCK

The wind and exposure factors caused a noticeable difference in the vegetation on the northern and southern sections of the rock. <u>Pinus rigida</u> and <u>Tsuga canadensis</u> were the dominant tree species on the northern section in places where there was a thin layer of soil. All these trees were dwarfed and deformed. Borings showed one specimen of Tsuga canadensis to be thirty years old. Its height was ten feet and its diameter breast high was 3.1 inches. Tree rings on the leeward side were much larger than those on the windward side.

The shrub stage on the northern section consisted of Gaylussacia baccata, Rhododendron catawbiense, Rhododendron maximum L., Viburnum cassinoides L., and Amelanchier laevis Wieg. with an undergrowth of Galax aphylla. Along the fringe of vegetated areas and on the bare rock were clumps of Cladonia rangiferina and Selaginella rupestris.

The southern section of the rock supported almost a continuous carpet of Selaginella-Cladonia mats, shown in Figure 10.

FIGURE 10

SELAGINELLA-CLADONIA MATS AND THIN SOIL PHASE

Sassafras albidum (Nutt.) Nees. and Quercus alba had gained a foothold. The undergrowth of these sections was composed of Corydalis sempervirens (L.) Pers., Polypodium vulgare, Selaginella rupestris and Cladonia rangiferina with a few plants of Iris and Panicum. Some of the thin soil sections contained Rubus sp. and Ribes cynosbati L.

Along the western fringe of the southern section of the rock was a thick growth of Tsuga canadensis, Kalmia latifolia, Rhododendron maximum, and Rhododendron catawbiense. There were plants of Polypodium vulgare, Athyrium Filix-femina (L.) Roth. and Polytrichium commune along the border in the undergrowth. Figure 11 shows Ephebe lanata (L.) Vainio and Gyrophora vellea (L.) Ach. growing on the rock in this vicinity.

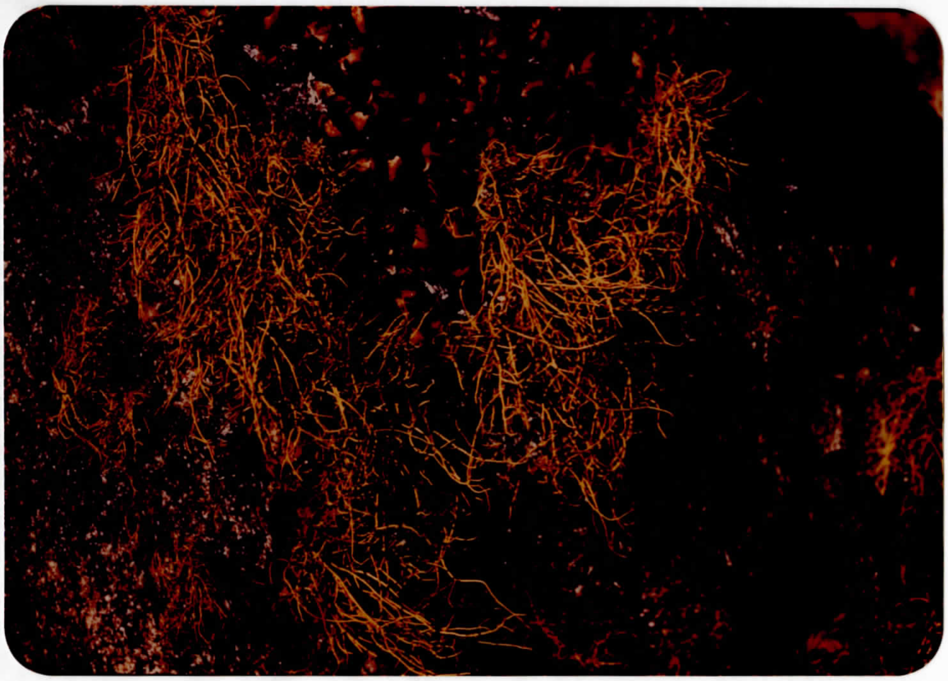

FIGURE 11

LICHENS EPHEBE LANATA AND GYROPHORA VELLEA

The eastern fringe of the southern section of the rock was composed mainly of *Kalmia* and *Rhododendron* with a few hemlocks moving in. The undergrowth contained *Lycopodium complanatum* L., *Selaginella rupestris* and *Cladonia rangiferina* slong the edge of the rock. There were some plants of *Quercus alba* gaining a foothold in various areas along this fringe.

Studies of the Forest Surrounding the Rock

It is not always easy to determine whether a community is a climax, as the most abundant species is not necessarily the dominant one, nor does it always compose the climax. If the same species of plants are present in the understory as in the topmost layer the community is generally a climax. If the understory is different from the topmost layer the stand is not reproducing itself and succession is in progress.

Data secured from studies of Plot # A-1 showed the most abundant trees to be *Acer rubrum* L. in association with *Quercus borealis* Michx., as indicated in Table I. *Tsuga canadensis* and *Quercus alba* had gained some foothold and were accompanied by fewer specimens of *Quercus montana* Willd. and *Magnolia accuminata* L. The understory was composed of *Fagus grandifolia* Ehrh., *Hamamelis virginiana* L., *Betula lenta* L., *Betula lutea* Michx., *Amelanchier arborea* (Michx. f.), *Magnolia fraseri* Walt., *Sassafras albidum*, and *Viburnum cassinoides*. There were many small plants of *Smilax* and *Amelanchier*. The

TABLE I

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # A-1

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	107	26	3	5
Acer rubrum	42	12		1
Quercus borealis	21	6	1	1
Tsuga canadensis	10			1
Quercus alba	6	3		1
Quercus montana	3	2	2	1
Magnolia accuminata	4	2		
Fagus grandifolia	5			
Hamamelis virginiana	5			
Betula lenta	4			
Betula lutea	3			
Amelanchier arborea	2			
Magnolia fraseri		1		
Sassafras albidum	1			
Viburnum cassinoides	1			

diameters breast high of Amelanchier were less than one inch, therefore, were not shown in Table I.

The soil in this plot was very thin and the moss Grimmia was growing on some of the exposed areas of rock. **Selaginella** accompanied it in some areas near the main rock.

There were no live chestnuts whose diameters breast high were more than one inch, but the plot contained many dead ones of all sizes. Most of the large trees, oaks and chestnuts, were fire scarred.

Data secured from studies of Plot # C-3 showed the most abundant tree to be Quercus alba, which was followed in abundance by Quercus borealis and Acer rubrum, as shown in Table II. The most common trees of the understory were Hamamelis virginiana and Nyssa sylvatica Marsh. Magnolia fraseri and Quercus montana were gaining a foothold. Other trees of lesser importance were Quercus muehlenbergii Engelm., Robinia pseudocacia L., Liriodendron tulipifera L., and Magnolia accuminata. The one species of Quercus stellata Wangenh. was the giant of the plot. Its diameter breast high was 18.6 inches and its height approximately seventy feet.

This plot presented tangles of undergrowth composed of Smilax, Rhododendron catawbiense, Rhododendron maximum, and Tsuga canadensis, all with diameters breast high of less than one inch. There were also many dead chestnuts of all sizes in the plot. None of the sprouts in this area were living.

TABLE II

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # C-3

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	155	45	2	2
Quercus alba	37	19	1	1
Hamamelis virginiana	39			
Quercus borealis	20	14	1	
Nyssa sylvatica	30			
Acer rubrum	20	4		
Magnolia fraseri	4	2		
Quercus montana	1	4		
Quercus muehlenbergii	2			
Robinia pseudocacia	1	1		
Liriodendron tulipifera		1		
Magnolia accuminata	1			
Quercus stellata				1

Data secured from studies of Plot # D-7 showed the most abundant large trees to be Quercus borealis and Quercus alba, as shown in Table III. Hamamelis virginiana was the most abundant in number, but all these had diameters of less than five inches. Amelanchier laevis was as numerous as Quercus alba, but composed the understory rather than the topmost layer. Other plants composing the understory were Clethra accuminata Michx., Magnolia accuminata, Acer rubrum, Viburnum cassinoides, Magnolia fraseri, Robinia pseudocacia, and Sassafras albidum. Castanea dentata (Marsh) Bork. composed an important part of the understory, but these were limited to sprouts from the dead trees and none were more than fifteen feet in height or had a diameter breast high of more than 1.8 inches.

There were many plants of Rhododendron maximum, Rhododendron catawbiense, and Kalmia latifolia, which helped to make up the understory. Some of these had diameters up to two inches with heights up to fifteen feet. There were a few small plants of Tsuga canadensis and Smilax.

Data secured from studies of Plot # F-1 showed the most abundant tree to be Tsuga canadensis. Some of these trees reached heights up to eighty feet or more, even though growth conditions were unfavorable due to thin soil and constant wind.

The understory was composed mostly of dense tangles of Smilax, Rhododendron catawbiense, Rhododendron maximum, and

TABLE III

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # D-7

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	156	6	4	6
Hamamelis virginiana	85			
Quercus borealis	11	3	3	1
Quercus alba	9	1	1	5
Amelanchier laevis	16			
Clethra accuminata	9			
Castanea dentata	8			
Magnolia accuminata	6			
Acer rubrum	4	1		
Viburnum cassinoides	3			
Magnolia fraseri	1	1		
Robinia pseudocacia	2			
Sassafras albidum	2			

Kalmia latifolia. Many of the laurels and rhododendrons had heights of twenty feet with diameters of over four inches. Other understory plants of lesser importance were *Viburnum*, *Clethra*, *Galax*, and *Polypodium*.

Other trees ranging from the understory to the topmost layer were *Magnolia fraseri*, *Acer pennsylvanicum*, *Betula lutea*, and *Acer rubrum*. Those occurring in lesser frequencies were *Nyssa sylvatica*, *Hamamelis virginiana*, *Betula lenta*, *Sassafras albidum*, *Sorbus americana* L., *Magnolia accuminata*, and *Quercus alba*. This data is presented in Table IV.

Data secured from studies of Plot # F-4 showed the dominant tree to be *Pinus rigida*. As this plot was located on top of the rock, the pines were all dwarfed and deformed as results of thin soil and constant wind. Borings of the center tree in the plot showed this *Pinus rigida* to be one hundred four years old. Its diameter breast high was 12.1 inches and its height twenty-five feet, which was the tallest in the entire plot. Tree rings on the leeward side were larger than those on the windward side.

There were many plants of *Nyssa sylvatica*, *Amelanchier laevis*, *Sassafras albidum*, *Rhododendron maximum*, *Rhododendron catawbiense*, *Kalmia latifolia*, and *Tsuga canadensis*, but all were dwarfed and deformed. Most had diameters less than one inch. Along with these were growing numerous small plants of *Gaylussacia baccata*. The undergrowth in this plot was com-

TABLE IV

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # F-1

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	52	30	8	9
Tsuga canadensis	17	12	5	9
Magnolia fraseri	7	4	1	
Betula lutea	11			
Acer pennsylvanicum	6	2		
Acer rubrum	5	3		
Nyssa sylvatica		1	2	
Hamamelis virginiana	3			
Betula lenta	2	1		
Sassafras albidum		3		
Sorbus americana		3		
Magnolia accuminata		1		
Quercus alba	1			

posed of Galax aphylla with some Cladonia and Selaginella along the fringe of the rock. Data for this plot are presented in Table V.

There were several dead chestnuts in this plot, but no sprouts were living either. Several of the pines had also died, all being deformed due to the wind.

Data secured from studies of Plot # G-7 showed the most abundant species of trees to be Hamamelis virginiana. However, Quercus borealis was the dominant topmost layer. Amelanchier laevis composed a large part of the understory along with Hamamelis. Other trees gaining a foothold in this area were Acer rubrum, Quercus alba, Magnolia accuminata, Quercus montana, and Magnolia fraseri. Smilax was also present.

There were several live sprouts of Castanea dentata growing out of the dead stumps, but none were over twelve feet in height and none had a diameter breast high of more than 1.2 inches. There were many large dead chestnuts lying on the ground in this area.

The giants of this plot were two specimens of Quercus rubra L., both attaining heights of over seventy-five feet. Their diameters breast high were 27.9 and 29.9 inches. Although acorns from these two red oaks were plentiful on the ground around them, there were no young trees of the same species growing in this area. Both of these red oaks showed

TABLE V

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # F-4

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	34	15	3	0
Pinus rigida Nyssa sylvatica Amelanchier laevis Sassafras albidum	6 20 7 1	15	3	

evidence of fire scars. Data for this plot are presented in Table VI.

Data secured from studies of Plot # I-12 showed Hamamelis virginiana to be the most abundant in number. The topmost layer of trees was composed of Acer rubrum, Quercus borealis, Tsuga canadensis, and Quercus rubra. There was one specimen of Quercus alba which attained a height of approximately eighty feet and had a diameter breast high of 19.0 inches. Tsuga canadensis, the center tree in the plot, was the largest in the area. Its approximate height was ninety feet and its diameter breast high was 31.5 inches.

In this plot there was one large outcropping of rock on a slope. Figure 12 shows one of the lichens growing on

FIGURE 12

FOLIOSE LICHEN UMBILICARIA SP.

TABLE VI

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # G-7

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	176	26	5	3
Hamamelis virginiana	79			
Quercus borealis	28	13	1	
Amelanchier laevis	35			
Acer rubrum	8	2	1	1
Quercus alba	7	1	2	
Magnolia accuminata	4	3	1	
Quercus montana	4	4		
Magnolia fraseri	5	2		
Castanea dentata	3			
Robinia pseudocacia	1	1		
Acer pennsylvanicum	2			
Quercus rubra				2

the slope in this and other areas of Flat Rock. Other plants composing the understory were _Betula lenta_, _Quercus montana_, _Quercus muehlenbergii_, _Amelanchier arborea_, _Acer pennsylvanicum_, and _Betula lutea_. _Rhododendron maximum_ was also abundant in this plot.

There were no live chestnut sprouts in this area, but there were many dead ones. In one spot near a chestnut was a clump of _Monotropsis odorata_ Ell. See Table VII for the presentation of data in this area.

Data secured from studies made of Plot # J-5 showed the area to be composed mostly of _Nyssa sylvatica_, _Tsuga canadensis_, and _Betula lenta_. Other plants found in the area were _Quercus palustris_ Muenchh., _Sassafras albidum_, _Kalmia latifolia_, _Rhododendron_, _Gaylussacia baccata_, and _Viburnum lentago_, which were all under 1.0 inch in diameter.

Growing in many of the crevices were clumps of _Selaginella_, _Cladonia_, and _Polypodium_. _Lecanora atra_ and _Umbilicaria pulustata_ were growing on exposed areas of the rocks.

All the plants in this plot were either dwarfed or deformed, or both. Continuous wind and thin soil were prominent factors here. Borings of one _Sorbus americana_ showed it to be diseased in the center. The nature of this disease was not determined. Growth rings were extremely close together, but its age was calculated to be between twenty and thirty years old. The diameter breast high was 1.1 inches and its

TABLE VII

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # I-12

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	112	16	9	6
Hamamelis virginiana	37			
Acer rubrum	24	5		1
Quercus borealis	14	8	5	1
Tsuga canadensis	14	1		1
Quercus rubra	2	1	4	2
Betula lenta	9			
Quercus montana	2	1		
Quercus muehlenbergii	3			
Amelanchier arborea	3			
Quercus alba	1			1
Acer pennsylvanicum	2			
Betula lutea	1			

height was eight feet. Data for this plot are presented in Table VIII.

The forested area outside the fifth-acre plots and along the eastern edge of the northern portion of the rock was found to be composed of dwarfed and deformed species of Tsuga canadensis, Nyssa sylvatica, Amelanchier, Sorbus americana, Quercus palustris, and Quercus alba. Borings into one specimen of Quercus alba, which was located about fifteen feet from the eastern edge of the rock, showed it to be at least seventy years old, but its height was only about twenty-five feet and its diameter breast high was 11.8 inches. Undergrowth through this area was composed of Rhododendron and Kalmia mixed with some Gaylussacia and Galax.

Throughout the whole forested area Hamamelis virginiana was abundant in the understory. This was often associated with Clethra accuminata, Vaccinum, Viburnum, Menziesia, or Rhododendron calendulaceum (Michx.) Torr.

Second in abundance to Hamamelis were plants of Rhododendron catawbiense, Rhododendron maximum, Kalmia latifolia, and Amelanchier. In many areas of the forest the Rhododendron and Kalmia presented an almost impassable undergrowth, especially when they were accompanied by Smilax.

TABLE VIII

QUANTITATIVE DISTRIBUTION OF TREES IN PLOT # J-5

Inches d.b.h.	1-4	5-9	10-14	15 -
Number of trees	21	2	0	0
Nyssa sylvatica	7			
Tsuga canadensis	5	1		
Betula lenta	4			
Amelanchier laevis	1	1		
Sorbus americana	2			
Quercus palustris	1			
Sassafras albidum	1			

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Investigations of the Flat Rock area have shown it to be a typical xerosere. The habitat has developed from the extreme of xeric conditions to the mesophytic forest. Each plant population has exerted its influence upon the habitat. Each has made the conditions more fit for the next community, from the crustose lichens, foliose lichens, mosses, and herbs to shrubs and trees. In so doing, the conditions have become less suitable for optimal growth of the existing community.

Once crustose lichens had lost their foothold to foliose forms the succession on the xerosere did not reverse itself. It was found that the crustose lichens *Lecanora atra* and *versicolor* were being crowded out by the foliose forms of *Umbilicaria* and *Parmelia*. These in turn were losing their dominance to the fruticose lichen *Cladonia*. *Selaginella* was growing in many of the mats with *Cladonia*, but was not necessarily dependent upon it to become established. Many mats of *Selaginella* were growing on the bare rock without any indication of crustose or foliose lichens having preceded them. In many areas the moss *Grimmia* was gaining a foothold on the rock, while in other areas it was in association with *Cladonia* and *Selaginella*.

In areas of thin soil, either in depressions or crevices in the rock, the herbaceous-shrub stage had moved in and was struggling to maintain its hold. This stage in the succession was composed of such species as Galax, Polypodium, Polytrichum, Gaultheria, Gaylussacia, Kalmia, and Rhododendron, with some Viburnum and azaleas moving in on the thicker mats.

The tree phase on the rock had not progressed past the stage of dwarfed and deformed plants consisting of Sassafras, Quercus, Amelanchier, Tsuga, and Pinus rigida. The dwarfing and deforming was due not only to the thin soil factor and lack of nutrients, but also to the factor of constant wind. Only those plants able to survive these extremes were able to germinate.

Data secured from studies of the region indicated the presence of two life zones in the area. The southern portion, which was less exposed to wind, was a typical deciduous forest of the oak-maple type with hemlocks and rhododendrons moving in around the outcroppings of rock. The southern portion of the main rock was almost entirely covered with thick mats of Cladonia and Selaginella.

The northern and western portions, which were under the influence of constant wind and lower temperatures, resembled the Canadian life zone, which is typically evergreen. In this section the hemlocks were dominant with rhododendrons comprising the majority of the understory.

The forest in general has progressed from an oak-chestnut association to an oak-maple association. Reed's earlier study (57) of the region indicated that chestnut trees comprised over 45 per cent of the forested area. At that time the trees occurring with the chestnuts, in order of importance, were red maple, chestnut oak, red oak, cucumber, and white oak. Locust, yellow poplar, pignut and mockernut hickories, scarlet oak, and black oak were rare.

The investigations of the present forest area of Flat Rock have revealed the presence of numerous dead chestnuts scattered throughout the entire forest. These trees had been killed by blight since Reed made his study in 1905 (57). But the other major trees of the forest, as indicated by Reed, were still present, Data secured by the study indicated the most abundant species, other than Hamamelis, to be Quercus borealis. Others, in order of abundance, were Acer rubrum, Quercus alba, and Tsuga canadensis. Table IX summarizes the findings of all the plots. There were still no species of Carya, and very few species of Liriodendron and Robinia were found. Most of the specimens of Robinia found were diseased or already dead. The live ones recorded were partially dead.

Few other species of trees, except chestnuts, showed evidence of any disease. However, some of the trees in every plot bore evidence of fire. Even those trees down over the western slope were fire scarred, as were many of the larger

TABLE IX

COMPARISON OF PLOTS SHOWING FREQUENCY OF SPECIES

Plot number	A-1	C-3	D-7	F-1	F-4	G-7	I-12	J-5	Trees per acre
Hamamelis virginiana	5	39	85			79	37		153.0
Quercus borealis	29	35	18			42	28		95.0
Acer rubrum	55	24	5			12	30		78.8
Quercus alba	10	58	16	1		10	1		60.0
Tsuga canadensis	11			43			16	6	47.5
Amelanchier laevis		16			7	35		2	37.5
Nyssa sylvatica		30			20			7	35.6
Magnolia fraseri	1	6	2	12		7			17.5
Quercus montana	8	5				8	3		15.0
Pinus rigida					24				15.0
Magnolia accuminata	6	1	6	1		8			13.8
Betula lenta	4						9	4	10.6
Betula lutea	3			11			1		9.4
Castanea dentata			8			3			6.9
Quercus rubra						2	9		6.9
Clethra accuminata			9						5.6
Sassafras albidum	1		2	3	1			1	5.0
Robinia pseudocacia		2	2			2			3.8
Fagus grandifolia	5								3.1
Quercus muehlenbergii		2					3		3.1
Sorbus americana				3				2	3.1
Amelanchier arborea	2						3		3.1
Viburnum cassinoides	1		3						2.5
Acer pennsylvanicum						2	2		2.5
Lirodendron tulipifera		1							.6
Quercus stellata		1							.6
Quercus palustris								1	.6

laurels and rhododendrons in that area. Further proof of fire was the presence of _Betula lenta_ and _lutea_. _Betula_ is a typical indicator of previous fire in a forest community, and these two species were found throughout the entire area, although more abundant in some locations than in others. _Gaylussacia_ is another indicator of previous fire, but these plants were found only along the main rock and its fringes.

The most abundant species of the understory in the forest were _Rhododendron_, _Kalmia_, _Hamamelis_, _Amelanchier_, and _Smilax_. _Vaccinium_, azaleas, _Menziesia_, and _Clethra_ were present in scattered areas, but did not play an important role in the understory.

For a complete list of all the species of plants found in the Flat Rock area see Appendix B. The plants are listed according to Gray's classification scheme (13).

A record of animal life at Flat Rock was kept while making the study of the area. See Appendix A for a list of these animals. It should be noted that these animals were observed during the fall, winter, and early spring months during the period when many species had either migrated or hibernated.

Conclusions

The environmental conditions on the bare rock are very severe for most of the plants. There is no protection from the wind and evaporation is rapid, thus causing moisture conditions to be variable. Most of the depressions which collect water soon become dry as a result of the sun and wind. These severe conditions on the rock have resulted in a type of plant succession which has been extremely slow.

The stunted trees present on the rock can never become dominant until the rock has become sufficiently covered with a layer of soil deep enough for the seedlings to grow and reproduce themselves. Gradually the vegetation of the forested area will slowly creep its way over the rock and the xerosere will become a mesophytic forest. Such a succession will take centuries. While the oaks are dominant at the present time, the indications are that the ultimate mesophytic forest will be a beech-maple community.

There are certain factors which are definitely influencing the community, other than the expected ecological factors of nature, such as wind, water, and animals. In this particular area the human influence is tremendous. Each time a mat of *Cladonia* and *Selaginella* is loosened, by being trampled upon, the community is affected. The plant associations which had progressed that far in the line of succession must begin again.

The investigations of the Flat Rock area have revealed other problems of concern which are associated with the xerosere and the surrounding mesophytic forest. The study of the ecological structure prevented further research into these problems. The writer feels that a study of the following topics would afford much greater insight into the succession from the xeric to the mesic associations.

1. A study of the wind factor and its effect upon dwarfing, deformation, and moisture.
2. A study of the soil factor and its effect upon controlling the species of plants in each association.
3. A study of the succession of crustose, foliose, and fruticose lichens as being pioneer soil builders in comparison with mosses as soil builders.
4. A study of the thin soil phase and the nutrients present.
5. An investigation of the diseases affecting both the locusts and the chestnuts.
6. A study of life in the rock pool subsuccessions.
7. A study of the animal life of the area and its effects upon the communities.

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APPENDIX

APPENDIX A.

ANIMAL LIFE FOUND AT FLAT ROCK

CLASS AVES

Pheucticus ludovicianus (Rose-breasted Grosbeak)

Dendroica coerulescens (Black-throated Blue Warbler)

Icterus galbula (Baltimore Oriole)

Hylocichla mustelina (Wood Thrush)

Corvus brachyrhynchos (Crow)

Junco hyemalis (Junco)

Sitta carolinensis (Nuthatch)

Toxostoma rufum rufum (Brown Thrasher)

Dendrocopus villosus (Hairy Woodpecker)

Cathartes aura (Buzzard)

Richmondena cardinalis (Cardinal)

Parus bicolor (Tufted Titmouse)

Bonasa umbellus (Ruffed Grouse)

Piranga olivacea (Scarlet Tanager)

Vireo olivaceus (Red-eyed Vireo)

Buteo jamaicensis (Red-tailed Hawk)

Colaptes auratus (Flicker)

Spinus tristis tristis (Goldfinch)

Turdus migratorius (Robin)

Parus carolinensis (Mountain Chickadee)

Pipilo erythrophathalmus (Towhee)

Cyanocitta cristata (Blue Jay)

Dumetella carolinensis (Catbird)

CLASS REPTILIA

Sceloporus biseriatus (Fence Lizard)

CLASS MAMMALIA

Sylvalagus virginiana (Rabbit)

Mephitis nigra (Skunk)

Sciuridae sp. (Squirrel)

Odocoileus virginiana (Deer)

Felix sp. (Wild Cat)

Tamias sp. (Chipmunk)

Scalopus aquaticus (Mole)

APPENDIX B.

ANNOTATED SPECIES LIST

EPHEBACEAE

Ephebe Lanata (L.) Vainio

STRICTACEAE

Stricta pulmonaria (L.) Bir.

CLADONIACEAE

Cladonia pyxidata (L.) Hoffm.
Cladonia rangiferina (L.) Web.
Cladonia cristatella Tuck.

GYROPHORACEAE

Gyrophora Dillenii (Tuck.) Mull. Arg.
Gyrophora vellea (L.) Ach.
Umbilicaria pustulata (L.) Hoffm.

LECANORACEAE

Lecanora atra (Huds.) Ach.
Lecanora versicolor (Pers.) Ach.

PARMELIACEAE

Parmelia conspersa (Ehrh.)
Parmelia sp.

USNEACEAE

Alectoria jubata (L.) Ach.
Usnea barbata (L.) Wigg.
Usnea florida (L.) Web.

CALOPLACACEAE

Caloplaca elegans (Link.)

PHYSICACEA

Physica stellaris (L.) Nyl.

POLYTRICHACEAE

Polytrichum commune L.
Polytrichum piliferum Schreb.

GRIMMIACEAE

Grimmia apocarpa (L.) Hedw.

BRYACEAE

Bryum caespiticium L.

LESKEACEAE

Thuidium delicatulum (L.) Mitt.

LYCOPODIACEAE

Lycopodium obscurum L.

SELAGINELLACEAE

Selaginella apoda (L.) Fern.
Selaginella rupestris (L.)

OSMUNDACEAE

Osmunda cinnamomea L.

POLYPODIACEAE

Dryopteris thelypteris (L.)
Athyrium Filix-femina (L.) Roth
Polypodium vulgare L.

PINACEAE

Tsuga canadensis (L.) Carr.
Pinus rigida Mill.
Pinus Strobus L.

LILIACEAE

Uvularia pudica (Walt.)
Smilacina racemosa (L.)
Maianthemum canadense Desf.
Polygonatum biflorum (Walt.) Ell.
Convallaria montana Raf.
Trillium undulatum Willd.
Smilax sp.

IRIDACEAE

Iris verna L.

CORYLACEAE

Betula lutea Michx.
Betula lenta L.

FAGACEAE

Fagus grandifolia Ehrh.
Castanea dentata (Marsh) Bork.
Quercus palustris Muenchh.
Quercus alba L.
Quercus montana Willd.
Quercus stellata Wangenh.
Quercus muehlenbergii Engelm.
Quercus borealis Michx.
Quercus rubra L.

MAGNOLIACEAE

Magnolia fraseri Walt.
Magnolia accuminata L.
Liriodendron tulipifera L.

LAURACEAE

Sassafras albidum (Nutt.) Nees.

PAPAVERACEAE

Sanguinaria canadensis (L.)
Corydalis sempervirens (L.) Pers.

SAXIFRAGACEAE

Tiarella cordifolia (L.)
Ribes cynosbati L.
Rubus sp.

HAMAMELIDACEAE

Hamamelis virginiana L.

ROSACEAE

Sorbus americana L.
Amelanchier arborea (Michx. f.)
Amelanchier laevis Wieg.
Fragaria virginiana Duchesne
Potentilla canadensis L.

LEGUMINOSAE

Robinia pseudocacia L.

ACERACEAE

Acer pennsylvanicum L.
Acer rubrum L.

VIOLACEAE

Viola papilionacea Pursh.
Viola blanda Willd.
Viola hastata Michx.

NYSSACEAE

Nyssa sylvatica Marsh.

CORNACEAE

Cornus florida (L.)

CLETHRACEAE

Clethra accuminata Michx.

PYROLACEAE

Chimaphila maculata (L.)
Monatropis odorata Ell.

ERICACEAE

Rhododendron catawbiense Michx.
Rhododendron maximum L.
Rhododendron calendulaceum (Michx.) Torr.
Menziesia pilosa (Michx.) Juss.
Kalmia latifolia L.
Gaultheria procumbens L.
Gaylussacia baccata (Wang.) K. Koch
Vaccinium sp.

DIAPENSIACEAE

Galax aphylla (L.)

PLANTAGINACEAE

Plantago major L.

RUBIACEAE

Mitchella repens L.

CAPRIFOLIACEAE

Viburnum cassinoides L.
Viburnum lentago L.

COMPOSITAE

Taraxicum officinale Weber.

APPENDIX C.

HERBARIUM LIST

STRICTACEAE

Stricta pulmonaria (L.) Bir.

CLADONIACEAE

Cladonia pyxidata (L.) Hoffm.
Cladonia rangiferina (L.) Web.

GYROPHORACEAE

Gyrophora Dillenii (Tuck.) Mull. Arg.
Gyrophora vellea (L.) Ach.
Umbilicaria pustulata (L.) Hoffm.

PARMELIACEAE

Parmelia conspersa (Ehrh.)

USNEACEAE

Alectoria jubata (L.) Ach.
Usnea barbata (L.) Wigg.
Usnea florida (L.) Web.

POLYTRICHACEAE

Polytrichum commune L.
Polytrichum piliferum Schreb.

BRYACEAE

Bryum caespiticium L.

LESKEACEAE

Thuidium delicatulum (L.) Mitt.

LYCOPODIACEAE

Lycopodium obscurum L.

SELAGINELLACEAE

Selaginella rupestris (L.)

POLYPODIACEAE

Athyrium Filix-femina (L.) Roth
Polypodium vulgare L.

LILIACEAE

Uvularia pudica (Walt.)
Smilacina racemosa (L.)
Maianthemum canadense Desf.
Polygonatum biflorum (Walt.) Ell.
Convallaria montana Raf.
Trillium undulatum Willd.

IRIDACEAE

Iris verna L.

PAPAVERACEAE

Corydalis sempervirens (L.) Pers.

SAXIFRAGACEAE

Tiarella cordifolia (L.)

ROSACEAE

Fragaria virginiana Duchesne
Potentilla canadensis L.

VIOLACEAE

Viola papilionacea Pursh.
Viola blanda Willd.
Viola hastata Michx.

ERICACEAE

Gaylussacia baccata (Wang.) K. Koch

RUBIACEAE

Mitchella repens L.